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Virtual Environments to Address Autistic Social Deficits

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Abstract: Background: *Autistic Disorder is defined by social and communicative impairments and restricted, narrow interests. Impaired motivation is also common. Several investigators have developed computer-based and virtual environment tools to address various issues in autism(1-5). Four projects at CUA address the social impairment.*

Method/Tools: *Face Processing. The prediction that autistic face processing impairment involves gaze differences was tested in an eye tracking study using a VR display. A replication in progress uses a monitor. Early Intervention. A virtual environment, with kiddie-ride, monitor display and eye tracker, is being tested. The goal is to induce young children with autism to attend to faces. Social Navigation. A joystick-navigable, first-person-perspective shopping mall is presented on a monitor. To locate objects, the user must move either between or around social and non-social obstacles. Data include user comments and path records. Training in Social Conversation. SIMmersion LLC™ are collaborating with us to develop a social conversation module for adults with Asperger's Disorder. A virtual character remembers the conversation and responds as would an actual interlocutor to the user's speech.*

Results: *Face Processing. Preliminary results (with headset) confirmed gaze differences(6). The replication is in progress. Early intervention. Reliability-testing is being completed. Social Navigation. Controls describe their avatar's actions in the first person, and refrain from walking between conversing characters. Data collection with persons with autism has begun. Training in Social Conversation. Development is in progress.*

Discussion: *The projects described above derive from the hypothesis that failure to establish species-typical face attention and processing itself undermines cognitive development(7). Accordingly face processing is targeted in young children, and compensatory training is addressed with older individuals. The challenge is to make the technology not only effective, but adequately entertaining to overcome autistic motivational barriers.*

INTRODUCTION

Autism Spectrum Disorder (ASD) is characterized by impairment in verbal and nonverbal communication skills and social interaction, and the presence of repetitive behavior and narrow, obsessive interests, according to the standard diagnostic criteria used in research over the past decade.[1] While ASD can be diagnosed as early as 18 months, and most individuals are diagnosed by or near the start of their educational career, some are not identified until later childhood or even adulthood.

Facial expressions and gestures often hold little meaning for individuals with ASD. As a result it can be very difficult for them to make sense of people's behavior. During adolescence and young adulthood some individuals with ASD develop enough insight to become aware that they are different from their peers, and experience loneliness and sadness.

Once thought to be rare, ASD and related disorders are now being identified in large numbers. Prevalence estimates range from 15 to 60 per 10,000 individuals.[2,3] The symptoms of autism can be mitigated and quality of life improved thanks to evidence-based treatments such as intensive, autism-specific intervention in early childhood,[4,5] and psychopharmacological interventions.[7,8] Despite the popular perception of autism as a disorder of childhood, most individuals with ASD are adults.

In summary, there is a large population of children and older individuals who have severe deficits in their ability to interpret facial expressions and other nonverbal behavior; and equivalent lacks in their ability to transmit communication through these channels. The ASD syndrome results in a variety of social impairments that constitute major obstacles to the individual's possibilities of achieving independence and sustained employment, and having friends and intimate relationships.

Interventions to modify the young child's developmental course, or to teach older individuals skills that were not acquired naturally in childhood cannot approach in duration or intensity the on-going, unavoidable social instruction that is experienced by typically developing individuals. The most intensive autism intervention programs are offered primarily to young children (generally aged two to four), and these programs target a range of skills, among which social interaction is not an important focus. Intensive programs in social skill acquisition for older children are rare; for adolescents and adults with ASD they are largely unavailable, and the majority of such programs are not based on scientific evidence.

Virtual environments have been shown to be clinically useful for distraction from pain[8,9] and in the treatment of phobias[10-13] and are being investigated for their applicability to a number of other medical and psychiatric problems. Several investigators have developed computer-based and virtual environment tools to examine social behavior in autism[14-16] and to improve face processing, emotion recognition, and social problem solving.[17-19] The Autism Research Group at The Catholic University of America shares this focus on exploiting computer and virtual reality technology to develop techniques to improve the social competence of individuals with autism.

Our motivation for approaching autism mitigation through the social deficits grew out of the recognition of the centrality of the social deficit in autism,[20] and observation and review of face processing impairments and presence of symptoms of anxiety and depression in individuals with ASD,[21] findings that continue to be confirmed in more recent studies (e.g., face processing impairment[22,23]; psychiatric comorbidity[25-28]). It was hypothesized that infant onset of symptoms of anxiety and depressive disorder could disrupt face attention, with the consequence that the bases of face processing would not be established during the period when the infant is most apt, biologically, neurologically and behaviorally, for face processing to take root.[29] Following is a brief description of four projects at CUA that address autistic social impairments: Face Gace, Early Intervention, the Virtual Mall, and development of a Simulation to Train Conversational Interaction

FACE GAZE

These studies addressed the hypothesis that autistic differences in face processing would have correlates in gaze behavior, specifically that people with ASD would not look at the same locations on the face as controls. By means of a VR headset in which an eye tracking camera was installed significant differences were found between groups: while typically developing participants looked at the interior of the face, persons with ASD showed a greater tendency to look at the periphery.[29] Since use of the headset excluded many potential participants, a replication using a monitor and desktop eye tracker was next undertaken. Preliminary analysis of these data has found a significant correlation between gaze at the eye area and lesser impairment on the social component of the Autism Diagnostic Interview- Revised (ADI-R),[30] an instrument that focuses primarily on the individual's behavior at age four. This finding suggests that deficits in early social development may have a lasting effect on how these individuals look at faces. Since foveal and perifoveal vision are restricted to a narrow angle, gaze directed at the facial periphery[29] or at the mouth[32] fails to take in with adequate acuity the information necessary for interpreting facial expression.

EARLY INTERVENTION

An outgrowth of this project has been to propose an intervention to teach young children with autism to direct their gaze to the eye area of the face, and to convey that attention to the eye area has inherent functional benefits. The goal of this project, therefore, is to develop and pilot a technique to induce children with ASD aged 24 to 54 months to attend to the meaningful areas of faces, and to make use of the information transmitted by them. In order to accomplish this it is critical to attract and sustain the child's participation, in addition to differentially rewarding the target gaze behaviors, as sensed by a desktop eye tracker. The rewards available for this purpose include a wide range of videos, and 'rides' in the 'kiddie' helicopter in which the monitor and tracker are installed. Current testing addresses the validity of our 'semi-automatic' calibration technique for children, and adjustments to the positioning of a child car-seat and head-rest for head stabilization adequate for reliable eye tracking. A pre-pilot study beginning in May will assess the feasibility of the training schedule for children and their families.

VIRTUAL MALL

Young children with autism may exhibit a variety of reactions to finding themselves in large, busy environments such as airports and shopping malls. Among the reactions particularly disconcerting for parents can be an apparent insensitivity to the presence of other people, treating them as mildly inconvenient obstacles that will give way on approach or even contact. As adolescents and adults, some people with ASD still seem unaware of social spatial conventions, walking between two people engaged in conversation with each other, or passing between a person and a display window at which she is looking. The Virtual Mall is being developed with the participation of non-disabled and ASD adults through an iterative design process, using standardized tasks to draw the user to explore the environment and encounter its social navigational challenges. The long-term goal is the development and evaluation of a clinically practical and ecologically valid assessment of social cognition, and a rehabilitation modality to improve the ability of individuals with ASD to function in everyday environments.

Data has been compiled from 8 participants' comments during and after performance of the tasks, as well as an automatically acquired record of their navigation paths. Participants to date have been 4 females and 4 males (one with an ASD diagnosis), 7 of whom were Caucasian and one African-American, ranging in age from 19-27 (Mean age 20.9).

Virtual activities were defined in detail for the human factors trials in order to assure that all participants experienced all of the challenges of the mall, including virtual humans and inanimate objects, situated at locations that require participants to navigate through or around them in order to reach their target. Placement and orientation of the virtual humans creates situations that are identical in terms of spatial properties (e.g. space between humans and walls, or between obstacles and walls) but differ importantly in social implications (e.g., passing between a person and a store window to which her back is turned, versus passing between two characters facing each other at a conversational distance vs. passing between two advertising signs). Choice of path and distance between the operator's avatar and obstacles (other humans, inanimate objects and walls) are interpreted as relating to participants' experience of the ecological validity of this environment. To the extent users' verbal descriptions, comments and navigational decisions suggest adequate ecological validity, the environment is considered to have potential as a tool for use in assessing and intervening with individuals with social impairments, including autism.

The controller used was a joystick with minimal displacement, that moved the avatar in the direction that force was applied. Participants were trained in the operation of the controls by following_a path through large virtual mall corridors, during which they were instructed to avoid collision with walls and obstacles. Next they were familiarized with the layout of the mall by following experimenter instructions to navigate to each of the individual stores. The target location task entailed navigating to four different stores to locate in each a box containing a colored, numbered sphere. The experimenter named the store in which the next target could be found, and the participant's task was to locate the box, which opened once s/he was within range, and to read out the number and name the color. Participants performed two runs of the target location task, each with a different order of shops, and runs were counterbalanced across participants.

Participants were asked to 'think out-loud' as they performed the tasks. This instruction was later modified to " Describe what you are doing." At the end of the session, participants were invited to comment on the experience and identify anything they liked or disliked.

Individual participant comments were recorded and were coded for indication of perceived realism in the environment. For example, use of the first person to refer to one's own avatar, and imputation of agency and/or mental state to other artificial humans were treated as indications of perceived ecological validity.

Participants' paths through the environment were recorded. After the first four participants' experience, speech output was added, and the distance of two sets of obstacles from the store entrances they blocked was increased. Visualizations of the paths taken by participants before and after these changes were implemented are

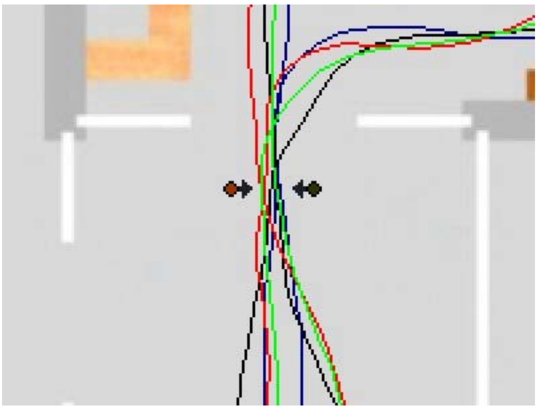
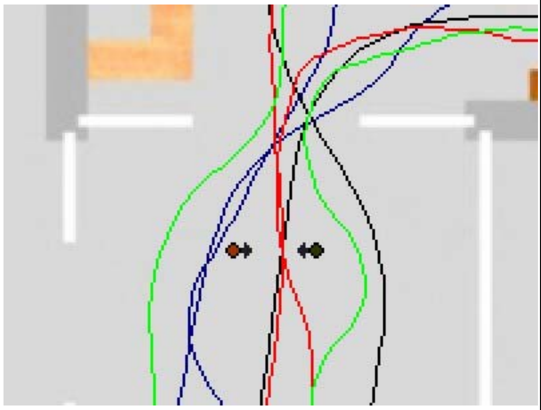
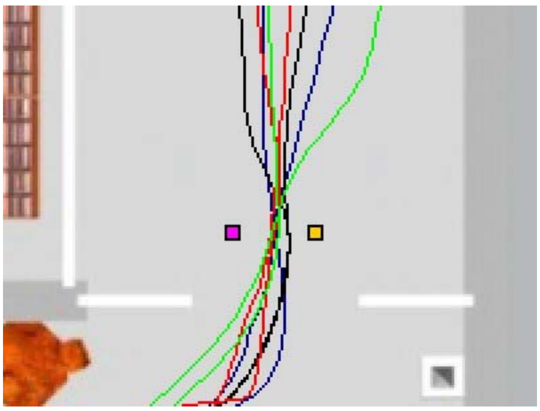
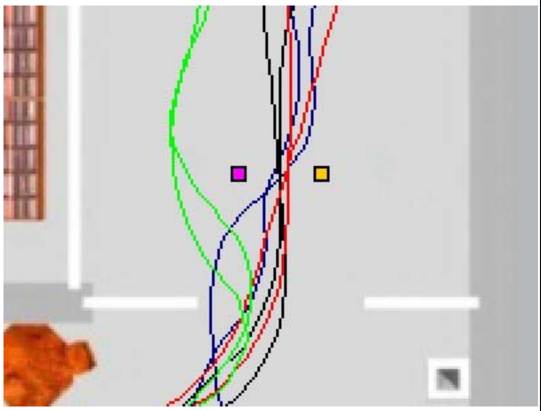
	Prior to revision (version 1)	After revision (version 2)
Social obstacles		
Non-social obstacles		

Figure 1.

shown in Figure 1. All four participants using Version 1 (no speech) walked between the two characters who were facing each other, both on entering and exiting the store, and., similarly, walked between the two inanimate objects. In contrast, participants who used the Version 2 of the mall, to which speech had been added, were more likely to walk around the now audibly conversing characters, rather than between them, while all navigated between the inanimate objects, despite the increased ease of circumnavigating both pairs of obstacles.

Figure 1: Paths taken in the vicinity of social (virtual humans) vs. non-social (objects) obstacles, by participants experiencing Versions 1 and 2 of the Virtual Mall. Arrows indicate the direction the virtual humans are facing. In Version 2 the two people facing each other can be heard to converse. In addition, in Version 2, both the pair of people and the pair of objects have been moved farther from the door, so that it is easier to go around both rather than passing between the two members of the pair.

Participants were able to learn rapidly to navigate the mall, and locate the targets. Review of participants' paths and their verbal comments during and after participation suggest that their navigational decisions reflect their awareness of social constraints. They used the first person in describing their avatar's movement and intentions, irrespective of whether they experienced a first-person or a third-person perspective. They tended to ascribe agency and even mental states to the virtual humans. One participant, passing near a virtual human, said "Excuse me!"

In addition, they tended to refrain from walking between characters who were facing each other, when the characters were audibly conversing. The gain in eliciting socially appropriate responses from addition of speech is a promising indication for further development of the mall as an evaluative and training tool. Additional design trials are planned with younger individuals with ASD and controls matched for nonverbal mental age.

SIMULATION TO TRAIN CONVERSATIONAL INTERACTION

Lack of success in initiating and, especially, in maintaining a conversation is a hallmark of ASD. The impoverished opportunities and poor success rate of peer interaction persists into older adolescence and adulthood,[32] presenting an obstacle to the casual social interaction that is a part of much of human activity. Participating in a conversation involves, among other things, turn-taking, gaining awareness of the topic of the conversation, interpreting the partner's nonverbal as well as verbal cues and knowing when and how it is appropriate to change the topic.

The Autism Research Group is collaborating with SIMmersion LLC™ to develop an interactive social conversation simulation for adults with high-functioning ASD.

In this system, the simulated character (represented by a data-base of video clips performed by an actor) remembers the conversation history and responds as would an actual interlocutor to the user's speech.

Structure is provided by the responses offered for the user's choice. The simulated character's verbal and nonverbal responses, and his willingness to continue the interaction provide intrinsic feedback.. At the same time, cues are available from a help agent in a separate window who enthusiastically applauds when the user chooses an appropriate question, and covers her face with both hands when the user's response choice is inappropriate. Each play of the simulation is different, the interaction is compelling, and there is the possibility of improving one's score each time. These game-like aspects of the simulation are expected to help motivate the user to play the simulation repeatedly and thus build his/her conversation skills.

The goal is to provide the individual with increasingly successful experience, supported, to the extent s/he chooses, with simplified instruction and reviewing of parts or all of the past conversation, that can be pursued in a nonthreatening environment, in order to develop a base of conversational skills.

DISCUSSION

Individuals with ASD have missed out on much of the experience required for social and cognitive development, possibly because of disruption to their development in infancy as a result of heavy genetic liability to anxiety/depressive disorders leading to very early onset of symptoms of these genetically related disorders (Trepagnier, 1996). These individuals require training appropriate to their developmental level to improve the success of their social interactions, thereby raising the likelihood that they will become more integrated into their community. Computerized and virtual reality technologies enormously broaden the scope of possible interventions. The dual challenge is to make technology-based interventions both efficacious in inculcating gains in social skills and entertaining enough to overcome autistic motivational barriers, so that consumers and their families, educators and clinicians will use and benefit from them.

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